Toward a Coupled Ocean-Wave-Atmosphere Moddel of Typhoon Impacts on the Western Pacific

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LONG-TERM GOALS

This work aims to understand the interation between ocean, wave and atmosphere under Typhoon condition. Applying the knowledge leaned to improve Navy ocean prediction capability.

OBJECTIVES

The first objective of this effort is to develop an ocean model to cover the Typhoon DRI study area at the West Pacific applying a Naval Research Laboratory (NRL) Ocean Nowcast/Forecast System (ONFS) (Ko et al., 2008). The second objective is to conduct real-time prediction applying the model to provide ocean conditions to support the field experiments. The third objective is to collaborate with other Typhoon DRI PIs as well as the PIs from related projects such as the Taiwanese ITOP (Interaction of Typhoon and Ocean Project) and TCS-08 (Tropical Cyclone Structure field experiment in the Western North Pacific) to study the impact of Typhoon and wave on the ocean applying models and observations. The finally objective is to use observational data to evaluate the model responses to Typhoon and apply the result to improve the operational applications.

APPROACH

To achieve the objectives an ocean model that covers the Typhoon DRI experiment area in the Western North Pacific Ocean is developed based on the NCOM (Navy Coastal Ocean Model, Martin, 2000). NCOM has been applied for operation at NAVO in a global scale (Barron, 2004) and a relocatable regional scale. One of the Navy's operational wave model, SWAN, is utilized to provide surface wave condition for ocean-wave interaction study in collaboration with Typhoon DRI PI S.-Y. Chao of University of Maryland. Navy operational meteorology products from NOGAPS and COAMPS are used to provide the surface forcing for the ocean and wave models. By using Navy operational ocean and wave models and meteorological products to conduct Typhoon impact studies, the results can be more directly applied to improve Navy's ocean/wave/meteorology prediction capabilities.

Real-time ocean nowcast/forecast experiments are conducted applying the ocean model or the East Asian Seas Nowcast/Forecast System (EASNFS) with realistic meteorology forcing from NOGAPS and COAMPS. Satellite altimeter data and MCSST are used for data assimilation to produce a realistic ocean conditions. Figure 1 shows the daily prediction for 2008/10/01 00Z. The real-time prediction and the derived products can be used for mission planning to support field experiments such as TCS-08 (Tropical Cyclone Structure field experiment in the Western North Pacific) at summer of 2008 and

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14. ABSTRACT
The first objective of this effort is to develop an ocean model to cover the Typhoon DRI study area at the West Pacific applying a Naval Research Laboratory (NRL) Ocean Nowcast/Forecast System (ONFS) (Ko et al., 2008). The second objective is to conduct real-time prediction applying the model to provide ocean conditions to support the field experiments. The third objective is to collaborate with other Typhoon DRI PIs as well as the PIs from related projects such as the Taiwanese ITOP (Interaction of Typhoon and Ocean Project) and TCS-08 (Tropical Cyclone Structure field experiment in the Western North Pacific) to study the impact of Typhoon and wave on the ocean applying models and observations. The finally objective is to use observational data to evaluate the model responses to Typhoon and apply the result to improve the operational applications

15. SUBJECT TERMS

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Typhoon DRI field experiment starting 2010. The real-time prediction will be serving as the baseline to evaluate against the predictions from the improved ocean model or forcing and wave coupling. The realistic prediction are also can be used in place of real ocean in a virtue field experiment to better design the experiment.

We will collaborate fully with the researchers from Typhoon DRI , ITOP and TCS-08. Contribute the model results and perform model twin experiments, together with observational, to conduct studies related to Typhoon. Subjects of interest are oceanic responses to Typhoons and the influences of ocean on the Typhoon intensity. We also plan to study the ocean-wave two-way interaction and investigate how the surface waves affect the ocean mixing, particularly under the Typhoon strong wind condition, and study the impact of Typhoon induced strong current on the wave model prediction. We expect to obtain the data from observations and apply the data to evaluate the ocean/wave model and Navy operational meteorology prediction used for the model forcing.

The knowledge leaned are then applied to improve the ocean and wave model prediction for transition to operation.

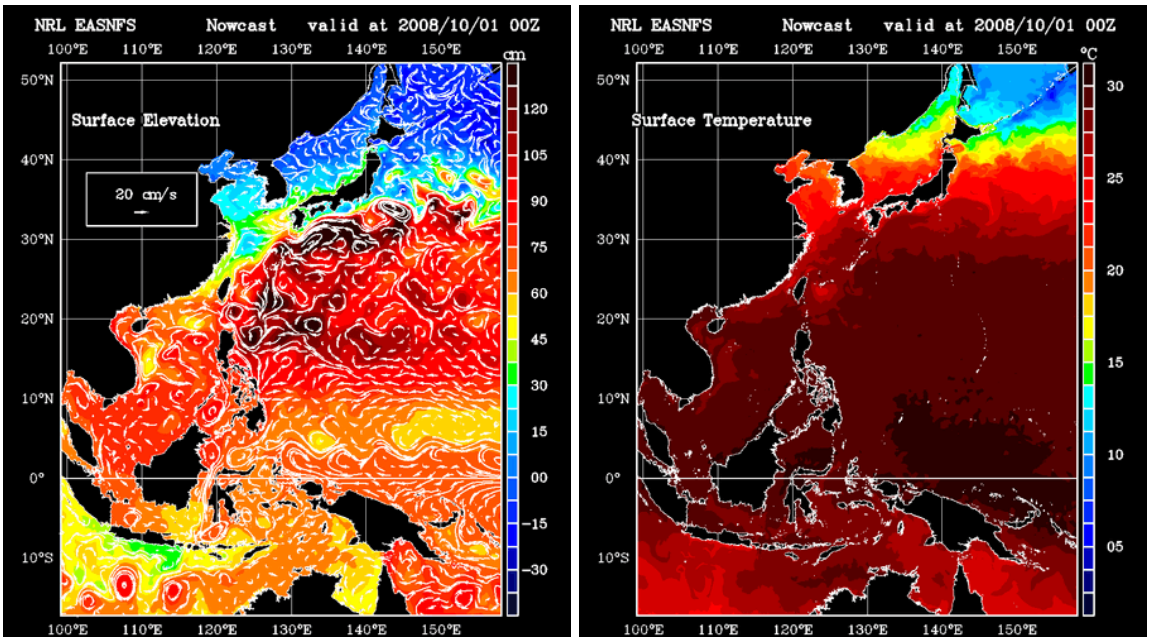

Figure 1. The NRL EASNFS prediction for 2008/10/01 00Z,. On the left, is the sea surface height and the current; on the right is the sea surface temperature.

WORK COMPLETED

Conducted real-time ocean prediction using NRL EASNFS on a daily base. Provided the ocean prediction products and the satellite remonte sensing products to support ONR Tropical Cyclone Structure (TCS-08) field experiment in the Western North Pacific over a website (http://nrlssc7320.navy.mil/NLIWI_WWW/EASNFS_WWW/TCS08.html). The daily ocean prediction products are also transimitted to UCAR TPARC/TCS-08 field catalog center

(http://catalog.eol.ucar.edu/tparc_2008/) in real-time to support TPARC/TCS-08 researches. The TCS-08 field observation, mainly the airbone AXBT temperature profile data, were obtained for the evaluation of the EASNFS prediction and for conducting the research.

In collaboration with Taiwan ITOP PIs, I.-I. Lin and C.-C. Wu of national Taiwan University conducted a study on the impact of the upper ocean thermal structure on the intensification of the category-5 typhoons at the Western North Pacific applying EASNFS. An article was submitted and published in a journal, the Monthly Weather Review, to report our findings.

In collaboration with ONR Typhoon DRI PI, S.-Y. Chao of University of Maryland, conducted research on the impact of Typhoon on an anomalous upwelling event at southern coast of Taiwan applying EASNFS and a high resolution coastal model. The findings were documented in an article and submitted to a journal, the Terrestrial, Atmospheric and Oceanic Sciences, for publication.

RESULTS

The NRL EASNFS was developed to support ONR NLIWI modeling effort in the privous years. The model prediction has been used for the open boundary condition for the high resolution models to study the non-linear internal waves at South China Sea, e.g., Chao et al (2007).

For the FY08, we attended 2 ONR sponsered worshops, one at Tiapei, Taiwan to discuss outline of research and experiment plan, and to forge cooperations with Taiwanese PIs on the ITOP. Attended another workshop at Miami for the planing of numerical experiments with Typhoon DRI PIs.

To make contribution with TCS-08 field experiment at West Pacfic, we have met with TCS-08 PIs and discussed the plan for collaborated works. Starting from May 1, 2008 to the end of October, 2008 we conducted a real-time ocean prediction experiment using EASNFS and produced daily ocean prediction to support the TCS-08. The ocean products includes the ocean heat content (Figure 2) and satellite altimeter data and MCSST from NAVO satellite data fusion center. A website was setup to provide the prediction and data in real-time. According to the report from CDR Daniel Eleuterio, the EASNFS ocean predition, in particular the ocean heat content, is very useful for fly mission planing and the model prediction matched up very well with AXBT measurements.

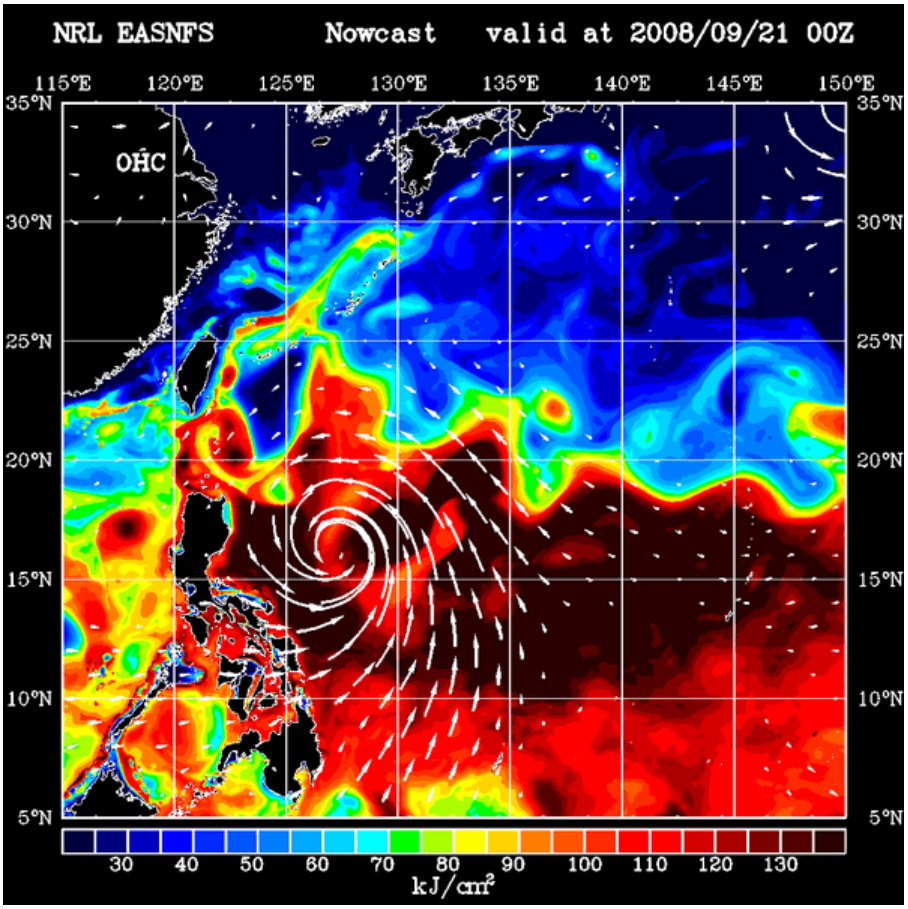

Figure 2. EASNFS real-time prediction for 2008/09/21 00Z in support of TCS-08 field experiment. The figure shows the prediction for the OHC (Ocean Heat Content) with NOGAPS wind stress superimposed to indicate the Typhoon location.

A study on the impact of the upper ocean thermal structure on the intensification of category-5 typhoons at the Western North Pacific was carried out in collaboration with ITOP PIs I.-I. Lin and C.-C. Wu. Our study shows that the ocean eddies which modifies the seasonal ocean thermal structure, particularly at a region north of 17N at the West Pacific Ocean, have a strong influence on the typhoon intensification. The mechanism responsible for the ocean-typhoon interaction is the ocean mixing. When a typhoon moving over a cold eddy the strong mixing reduces the sea surface temperature in a large amount and Typhoon is likely to weakening. On the other hand, over a warm eddy, the sea surface temperature will not drop substantially due to a thick warm mixed layer and the typhoon may intensify. During the typhoon season the ocean below 17N at West Pacific Ocean are warm and has a thick mixed layer, however. As the result the typhoon intensification is not effected by eddies below 17N. Figure 3 demonstrates importance of the ocean mixing in reducing the surface temperature under a passing typhoon based on a twin experiment, one with mixing and another with mixing turned off, applying EASNFS. The Ekman pumping due to strong divergence induced by the Typhoon cyclonic wind at sea surface and the sequential inertial gravity waves may further modified the ocean thermo structure. The Ekman pumping and the inertial gravity wave are less effective in modification of thermo structure near sea surface compared to the mixing and therefore have a less impact on typhoon

intensification. The study was reported in a journal article at the Monthly Weather Review (Lin et al., 2008).

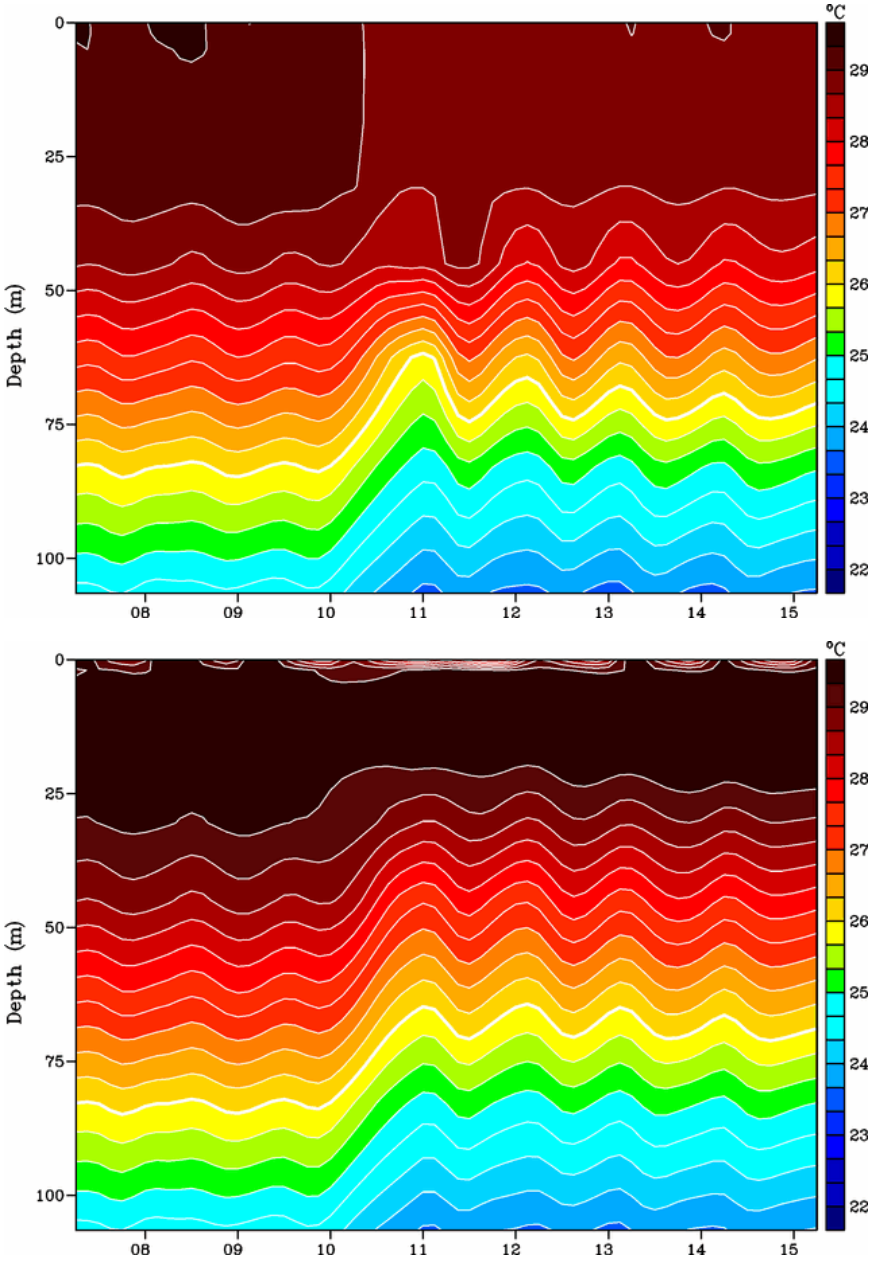

Figure 3. Temporal variation of upper ocean temperature responding to a moving typhoon obtained from a twin experiment conducted with EASNFS. On the top, near surface temperature drops immediately once impacted by the typhoon (at middle of day 10) due to a strong mixing. Turning off the mixing, the temperature does not change much as shown on the bottom. The temperature change at the surface is due to heat flux.

In collaboration with Typhoon DRI PI S.-Y. Chao, a study on the impact of typhoon on an anomalous upwelling event at southern coast of Taiwan was conducted applying EASNFS and a high resolution coastal model. The spring tide interacting with capes and their southward extension ridges often produces an intense upwelling at Nan Wan, a small bay at southern tip of Taiwan opens to the Luzon

Strait. Under normal conditions, the upwelled cold-water masses propagate away from Nan Wan in the form of internal Kelvin waves as shown in a sequence of plots (Figure 4) produced from model simulation. For the early July of 2009, the Typhoon Fengshen passes through the South China Sea invites Kuroshio intrusion, inducing a strong, eastward subtidal flow near Nan Wan (Figure 4). This strong eastward flow when superimposed on the ebb tide, blocks the internal Kelvin wave propagation, preventing the cold water to disperse (Figure 5). The extended period of cold water at Nan Wan results in a mass killing of fishes. The findings from this study were reported in an article and submitted to a journal, the Terrestrial, Atmospheric and Oceanic Sciences, for publication.

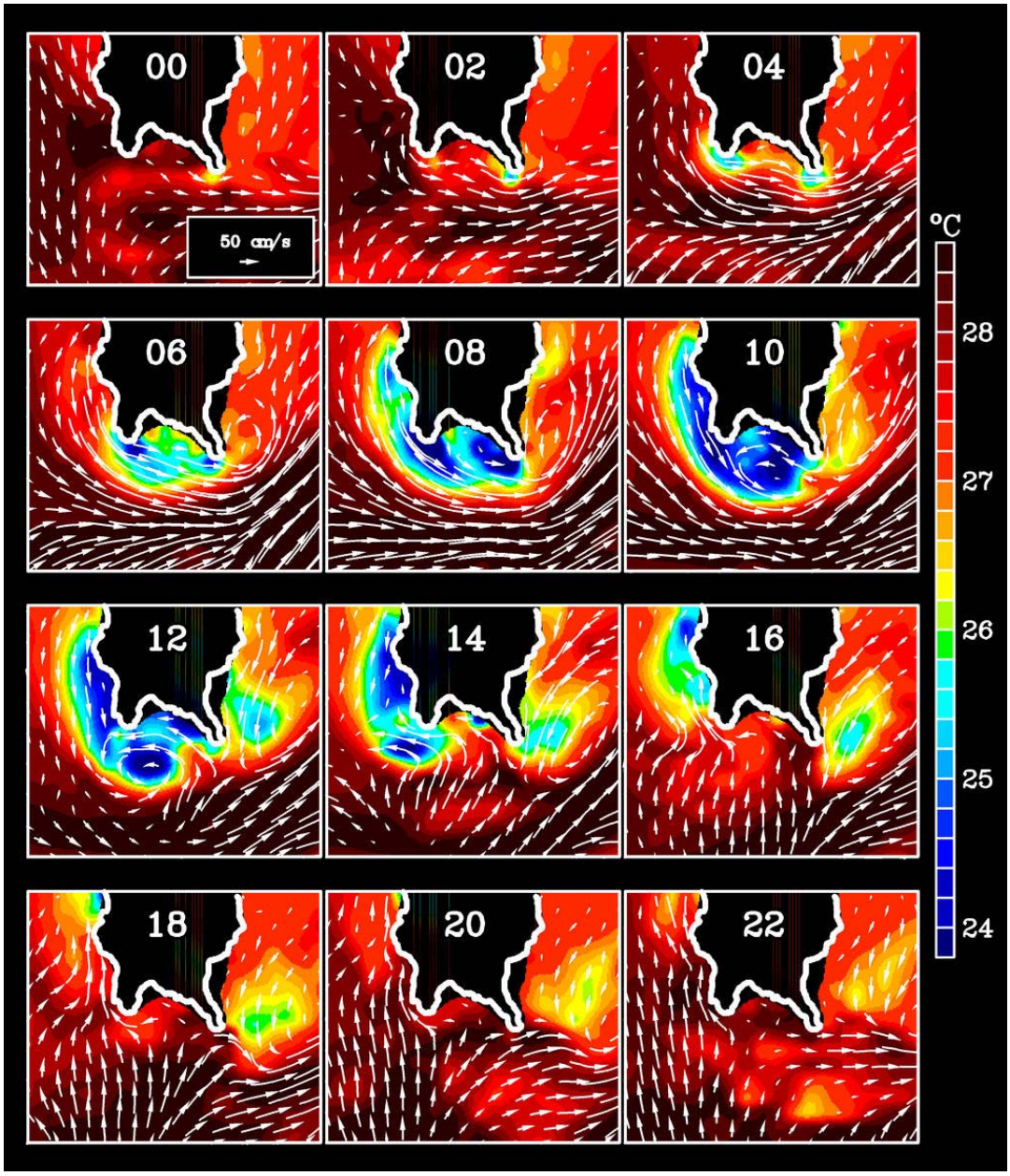

Figure 4. Bihourly currents and temperature at 25 m depth showing normal cold-water intrusion at Nan Wan during the spring tide. The cold waters propagate away from Nan Wan in the form of internal Kelvin waves.

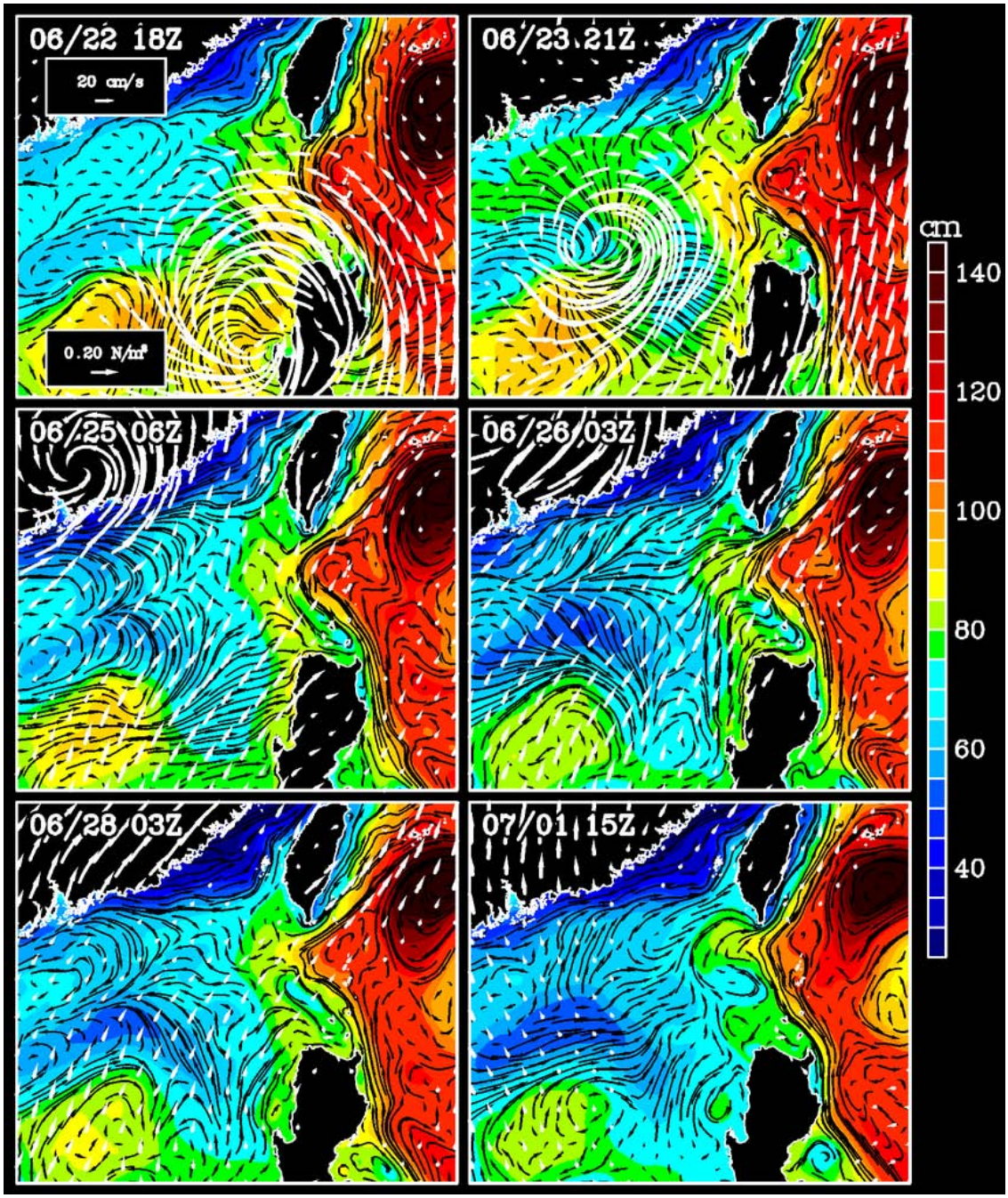

Figure 5. A sequence of ocean current and sea surface height variation predicted by EASNFS during and after passage of Typhoon Fengshen at South China Sea. Typhoon Fengshen invites Kuroshio intrusion at the Luzon Strait inducing a strong, eastward flow near Nan Wan at southern tip of Taiwan at early July, 2008.

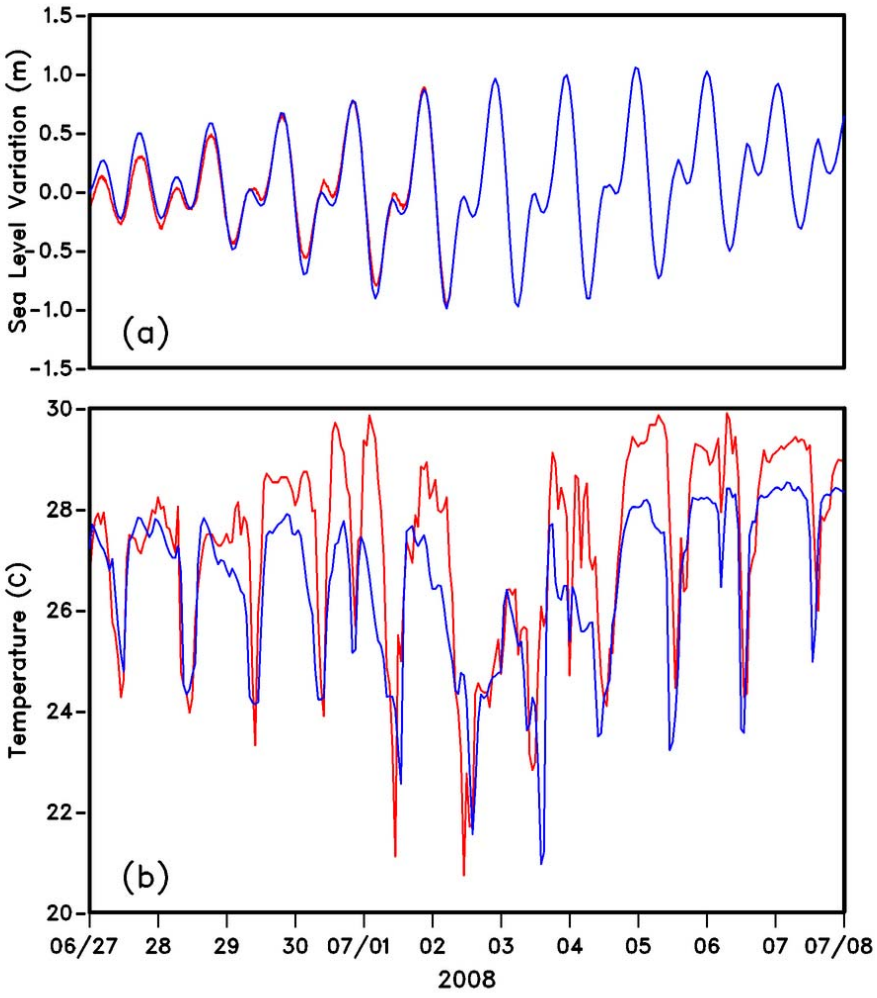

Figure 6. During early July, 2008, spring-tide induced cold upwelling water at Nan Wan was blocked by a strong eastward subtidal flow due to Typhoon Fengshen and failed to disperse. Over-cumulated cold water resulted in mass kill of fishes. The red line shows observation and black line shows model prediction.

IMPACT/APPLICATIONS

The real-time EASNFS ocean predictions were applied to the mission planning for the TCS-08 field experiment at the Western North Pacific. Results from studies outlined above suggest a strong interaction between ocean and typhoon. From study of Lin et al (2008), it suggests that to improve typhoon or hurricane prediction, the influence of the ocean mesoscale eddies and fronts has to be taken into account. The impact of typhoon on the ocean is far-reaching and in many forms as discovered in our study (Ko et al, 2008).

RELATED PROJECTS

NRL 6.2 Coupled Ocean-Wave Prediction System (PI/POC – Rick Allard) – PI serves as a convoy between two research groups.

ONR TCS08 – Provides Ocean prediction to support TCS08 field experiment and applies field observations to conducts collaborated researches.

ITOP (Taiwanese counterpart of ONR Typhoon DRI) – Exchanges data and conducts collaborated researches with ITOP PIs.

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